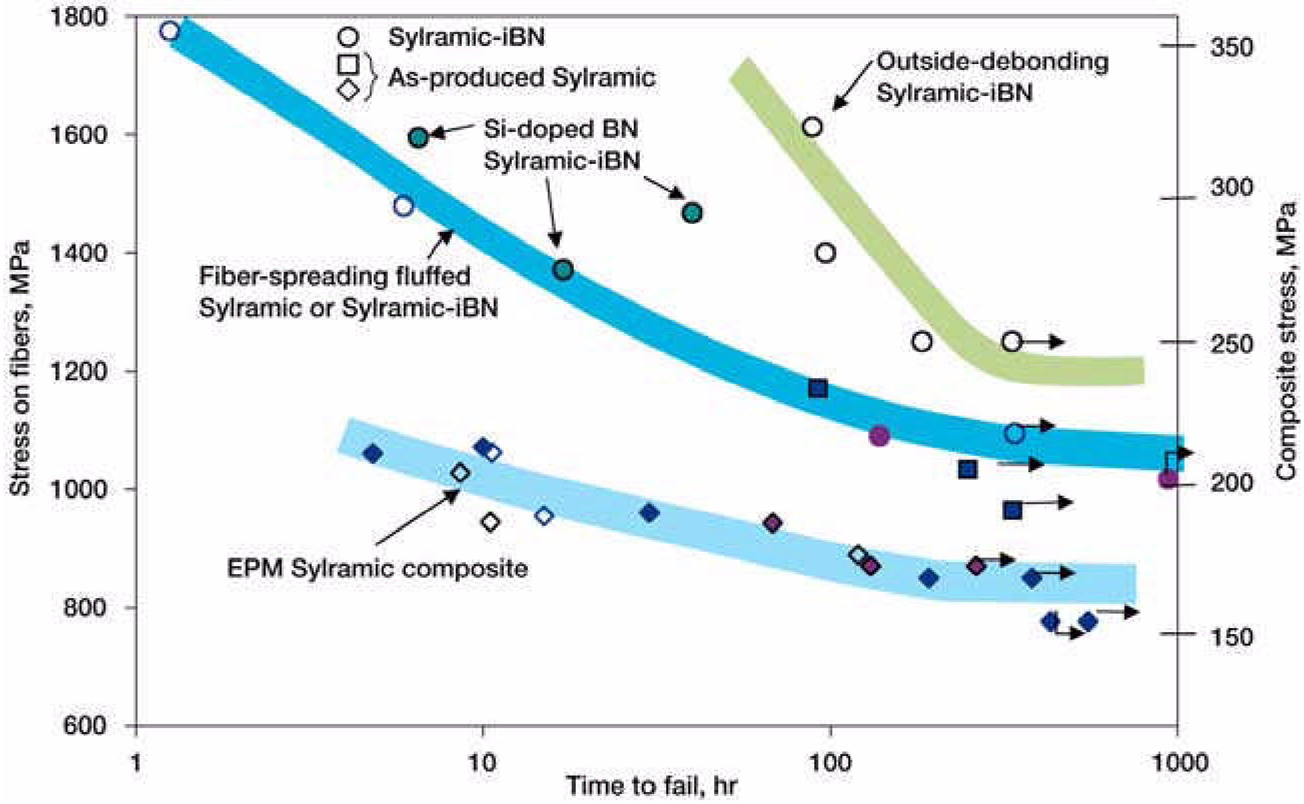
Ceramic Composite Intermediate Temperature Stress-Rupture Properties Improved Significantly

Silicon carbide (SiC) composites are considered to be potential materials for future aircraft engine parts such as combustor liners. It is envisioned that on the hot side (inner surface) of the combustor liner, composites will have to withstand temperatures in excess of 1200 °C for thousands of hours in oxidizing environments. This is a severe condition; however, an equally severe, if not more detrimental, condition exists on the cold side (outer surface) of the combustor liner. Here, the temperatures are expected to be on the order of 800 to 1000 °C under high tensile stress because of thermal gradients and attachment of the combustor liner to the engine frame (the hot side will be under compressive stress, a less severe stress-state for ceramics). Since these composites are not oxides, they oxidize. The worst form of oxidation for strength reduction occurs at these intermediate temperatures, where the boron nitride (BN) interphase oxidizes first, which causes the formation of a glass layer that strongly bonds the fibers to the matrix. When the fibers strongly bond to the matrix or to one another, the composite loses toughness and strength and becomes brittle.

To increase the intermediate temperature stress-rupture properties, researchers must modify the BN interphase. With the support of the Ultra-Efficient Engine Technology (UEET) Program, significant improvements were made as state-of-the-art SiC/SiC composites were developed during the Enabling Propulsion Materials (EPM) program. Three approaches were found to improve the intermediate-temperature stress-rupture properties: fiber-spreading, high-temperature silicon- (Si) doped boron nitride (BN), and outside-debonding BN. Fibers were spread by mechanically spreading tows in the woven cloth or by heat-treating woven cloth to produce an in situ BN layer on the fibers, which naturally increases the distance between neighboring fibers. High-temperature Si-doped BN has been applied as the interphase layer to woven cloth, which is then stacked to fabricate SiC matrix composites. The Si-doped BN contains little oxygen (<1 at.%) and approximately 7 at.% Si. Outside debonding describes BN interphases that have been processed to cause interfacial debonding and sliding between the BN interphase and the SiC matrix. The interface where debonding and sliding occurs for conventional BN-interphase composites is between the BN interphase and the SiC fiber. This enables the oxidizing environment to have direct access to the SiC fiber and causes more rapid strength reduction. Outside-debonding interphases dramatically slow down this process since the oxidizing environment is blocked to a great extent by the relatively thick BN interphase.



Improvements in stress-rupture at 815 °C in air.
Long description

Stress-rupture properties for several different composites with different BN interphases-fiber-spreading fluffed Sylramic or Sylramic-iBN, outside-debonding Sylramic-iBN, silicon-doped BN (Sylramic-iBN). The three modifications to the BN interphase all improved stress-rupture properties in comparison to the EPM Sylramic composite.

The figure compares the stress-rupture properties for current state-of-the-art material with SiC composites made with these three methods. It is evident that if these methods can be applied to new components, higher design stresses can be tolerated for the intermediate temperature regions of combustor liners. Work is continuing to combine some of these approaches and further minimize the strength reduction that occurs at intermediate temperatures.

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